GREAT LAKES
DREDGED MATERIAL TESTING AND EVALUATION MANUAL

APPENDIX D
SEDIMENT SAMPLING & HANDLING GUIDANCE

prepared by:

Jan A. Miller
USACE, Great Lakes & Ohio River Division

John L. Dorkin
USEPA, Region 5

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

1. APPLICABILITY

This appendix provides recommended procedures for the collection and handling of bottom sediments for chemical, physical and biological testing. Bottom sediments may be sampled and tested for a variety of purposes. The guidance provided here is directed toward a contaminant determination as part of the evaluation conducted in relation to Section 404(b)(1) of the Clean Water Act. These guidance and procedures may not be fully applicable to other study or project purposes. In addition, the sampling methods discussed here are appropriate for Great Lakes tributaries and nearshore areas. Procedures for deep-water sediment sampling are not discussed because these areas are not usually sampled as part of a 404(b)(1) evaluation.

A number of references are available which discuss sediment sampling procedures, including: USEPA (1977); International Joint Commission (1987 and 1988); Lowe and Zaccheo (1991); Mudroch and MacKnight (1991), and; ASTM (1991). These references should be consulted if the guidance provided here is not suitable for study or project purposes.

This appendix will first discuss the planning and design of a sediment sampling program. Sampling equipment, supporting equipment, and handling procedures will then be discussed.

2. PLANNING AND DESIGN

Prior to any field activities, sound planning is necessary to determine the type, number, location, and size of samples to be collected, and to assure that the samples are not altered, biased or contaminated in a way which would invalidate their use. The planning of a sediment sampling program should logically flow from the results of the tiered evaluation outlined in the regional guidance manual. Using the tiered testing approach, sediment and water samples may need to be collected on more than one occasion. The results of historic data compiled during Tier 1 may serve as the foundation for the design of a sampling program for Tier 2 testing. The results of Tiers 1 and 2 would direct the focus of sampling for Tier 3 tests, if necessary.

2.1 Objectives

The first, and perhaps most important step in developing a sediment sampling plan is to define the objectives, which are a function of the types of information needed and the decisions to be made with that information.

The information obtained from a sampling plan for a 404(b)(1) evaluation is used to evaluate potential contaminant impacts from the discharge of dredged material. However, the type of information needed for this evaluation may differ from tier to tier. In many cases, these differences result in different number of samples, sampling locations and sampling methods for each tier. For example, a few composited grab samples may be suitable during Tier 1 to confirm the applicability of an exclusion or to help develop a contaminant of concern list, but might not be appropriate for a Tier 2 or 3 sampling plan.

Data quality objectives (DQOs) are qualitative and quantitative statements of the overall uncertainty a decision maker is willing to accept in results or decisions derived from environmental data. A qualitative statement of the DQOs for contaminant determinations as part of a Great Lakes 404(b)(1) dredged material evaluation is provided in Appendix E.

In summary, the objectives of a sediment sampling plan should address the type of information to be obtained, the decisions that will be made with that information, and level of uncertainty that is acceptable for those decisions. These objectives should be elaborated in the written sampling plan.

2.2 Information Gathering

The types of data that should be compiled prior to initiating the sampling plan includes:

- proposed dredging depths and locations,
- water depths and level fluctuations,
- obstructions (bridges, pipelines, ships, etc),
- access sites for mobilizing equipment,
- sources of contaminants (point and non-point),
- navigation use (commercial and recreational),
- hydraulic/other factors affecting sediment distribution,
- historic sediment quality data,
- survey benchmarks for referencing elevations at sampling locations,
- landmarks for referencing sample locations, and
- emergency assistance (Coast Guard, hospitals, etc.).

Most of the above information should have been compiled as part of the Tier 1 evaluation. Many site-specific factors will affect where and how sediment samples need to be collected. The complexity of the sampling plan will mirror the complexity of the anticipated sediment contaminant distribution. If the dredging area has few sources of sediment contamination or a very predictable contaminant distribution, the sampling layout may be relatively uncomplicated with focus at a single or a few reaches or zones. However, if there is a complex set of sediment contaminant concerns throughout a dredging area, the sampling layout may be complex as well.

2.3 Management Units

In an ideal situation, all types of information would be available on every grain of dredged material. Due to to costs of sampling and testing, this is impractical. We must therefore attempt to make the best use of finite resources in evaluating the contaminant potential of dredged material. The recommended method is to "focus" the sampling and analysis in a series of steps, consistent with the tiered approach. This method begins by characterizing the dredged material at a large number of locations, using "coarse" (and inexpensive) analyses. Successive steps employ more sophisticated (and expensive) analyses at fewer locations.

Every sediment sample will represent some larger area or volume in the evaluation. It is recommended that the area or volume represented by a sample be defined as part of the planning process, prior to field activities, where practical. This should enhance the objectivity of the evaluation and interpretation of data.

A **management unit** is defined in the Inland Testing Manual (USEPA/USACE, 1998) as a "manageable, dredgeable unit of sediment which can be differentiated by sampling and which can be separately dredged and disposed within a larger dredging area". It is a spatially-defined volume of sediment located in a proposed dredging area for which the test results from a single sample (or composite) will be used to make a management decision about dredging or disposal. The management unit is therefore a decision unit.

In the case of a 404(b)(1) contaminant determination, the decision that needs to be made is whether or not open-water disposal of the volume of sediments within the management unit would be in compliance with the Guidelines with respect to sediment contamination. Two factors will be used to delineate management units; constructability and homogeneity.

A management unit must be constructible. That is to say that it must be practicable for normal dredging and disposal operations. A management unit could be as large as the entire dredging project area, or it could be a small portion of that area. A management unit should not be so small that it could not be dredged separately from other units. A management unit must also be constructible under a negative determination. That is, it must be possible to dredge other units and leave the one behind.

The homogeneity of the proposed dredged material, both physically and chemically, is the other factor to be used to delineate management units. Within a limited geographic area of a single waterway, it is reasonable to assume that sediments having similar physical and chemical characteristics would have similar potential for contaminant impacts. Although no predictable correlation between sediment chemistry and benthic or water column toxicity has been scientifically proven, the homogeneity of sediment physical and chemical properties is recommended as a reasonable basis for delineating management units and distributing sample locations.

2.4 Management Unit Delineation

Only a few generalizations about the appropriate size, number and distribution of management units can be made. The delineation of management units is very site specific, and should consider all available information. Ultimately, the decision relies on best professional judgment.

A subset of the information gathered about the dredging site should be considered in laying out the management units:

- proposed dredging depths and locations,
- water depths and seiche/tidal fluctuations,
- sources of contaminants (point and non-point),
- hydraulic/other factors affecting sediment distribution,
- and historic sediment quality data.

The first step is to map out the proposed dredging area. This is often not one contiguous area, but a number of shoals with varying surface areas and thickness. An example is shown on figure D-1. For a 404(b)(1) evaluation, sampling should be limited to the area to be dredged.

Information about the locations of known or suspected sources of contamination, factors affecting the movement of sediments and contaminants, and any historical sediment quality data can be used to estimate patterns of contaminant distribution in the proposed dredged material. The distribution of sediment contaminants in a riverine setting is generally more predictable than in the harbors and marinas at the mouths of Great Lakes tributaries. In the former case, sediment contaminants tend to be more spatially linked to specific sources of pollution. In the later, the contaminant distributions are complicated by the natural mixing of fluvial sediments from the river with littoral drift sediments moving along the near shore lake.

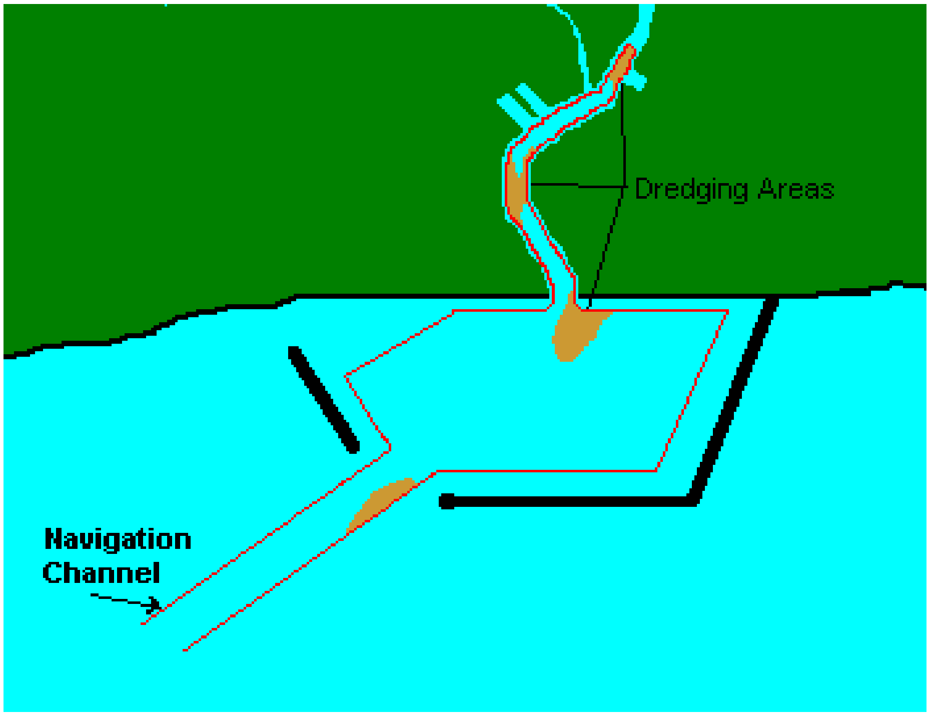

Figure D-1. Hypothetical Dredging Areas

The physical and chemical characterization of sediments is closely interrelated, and the distribution of many contaminants often parallel the distribution of sediment physical characteristics. All other factors being equal, the most likely place to find elevated levels of contaminants are at locations having fine-grained sediments with higher levels of organic matter. A knowledge of the principles of sediment transport combined with information about the hydraulics of a waterway can help identify portions of a proposed dredging area with sediments most likely to have the highest levels of contamination.

In cases where there is little or no existing physical or chemical data on a proposed dredged material or disposal site sediment, a visual survey of sediments from the area, collected with a grab sampler can yield highly valuable and inexpensive information. Field observations of sample odor and visual characteristics (see section 4.3), together with laboratory analysis of sediment grain size distribution (sieve analysis) and organic content (total volatile solids or total organic carbon) are quick and reliable indicators of the distribution of sediment contamination within a given area.

If the sediments are believed to be relatively homogeneous, management units should be delineated in a fashion that divides the dredging area into units of approximately equal volumes. If there is less historic data in one portion of the dredging area than others, or if existing information suggests that there is a greater probability for contamination in one portion of the dredging area than others, it is appropriate to delineate smaller management units in these areas. If there are known or suspected patterns of physical or chemical characteristics of sediments in the dredging area, it is appropriate to delineate management units in line with these patterns.

In some areas, the physical and chemical characteristics of sediments may change with depth. This is common in navigation projects that have not been dredged in many years or in areas of a waterway which took many years for a deposit to accumulate. In these cases, the sources of contamination may have changed or been eliminated, and less contaminated sediment deposits overlay older sediments with higher levels of contamination. In some projects involving "new work" dredging, a different pattern of vertical stratification can be found where surficial deposits of "recent", more contaminated sediments overlay uncontaminated deposits of sand or clay laid down in preindustrial times.

Sediment deposits which accumulate rapidly are less likely to have significant vertical stratification of contaminants. Areas that are routinely dredged every few years should, in most cases, need not be vertically divided into more than one management unit. In cases where there are suspected vertical patterns of sediment physical or chemical properties, it may be practical to consider different disposal alternatives for different layers or strata. Such sediment layering may form the basis of management unit delineation. For example, if the area to be dredged had a deposit of unconsolidated silty sediments overlying an older deposit of compacted sand, management units could be divided vertically at the interface of the deposits.

The size and delineation of management units should finally be checked for constructability. A management unit should not be less than 2 feet in thickness, which is the practical limit of accuracy for many dredges in open water. It should be remembered that if a management unit is determined to be unsuitable for disposal at the proposed disposal site, it may then represent a volume or area that is left undredged, or perhaps dredged and disposed at a different time. The delineation of management units should therefore consider the consequences of a negative or mixed determination as well as a positive one.

2.5 Sampling Plan for the Dredging Site

The type, number, and location of sediment samples are determined concurrently with the management unit delineation. In most cases a management unit is represented by a single sample. This may be a discrete sample collected at one location within the management unit or a composite of samples collected at several locations or depths. Because the results of analyses are intended to characterize the entire management unit, compositing is recommended, where practicable, especially for large management units. Sampling equipment, handling and compositing procedures are discussed in more detail later in section 3.

There are two general types of sediment samples; grab and core. Grab samples are collected from the sediment surface and core samples may be collected from depths within the sediment deposit. The collection of grab samples requires less supporting equipment, and generally costs much less than core samples.

Sediment deposits that are a foot or two in thickness can usually be sampled using grab sampling equipment. Thicker deposits that have accumulated rapidly, or have existing information suggesting that they are vertically homogeneous may also be sampled as surface grabs. Core sampling should be used in deposits where there are known or suspected vertical trends in sediment physical or chemical properties or if there is more than one management unit vertically.

It is recommended that grab samples comprise a composite of two or more grabs (of approximately equal volume) collected at locations within the management unit. Care must be exercised in collecting grab samples to avoid the loss of fine-grained sediments and the introduction of sampling bias. Large grab samplers (winch operated) and small clamshell dredge buckets (crane operated) will often obtain better sample recovery and deeper sample penetration than small, hand-held grab samplers.

Core samples should be collected for the entire thickness of the management unit, where practicable, and this length composited. Compositing of multiple cores within a management unit is desirable, but is often prohibitively expensive.

Dredging site water samples must be collected in order to prepare the elutriate as part of Tier 2 testing. Unless there is a significant difference in the quality of water at sediment sampling stations within the dredging area, in particular, differences in pH and redox potential, a single sampling location may be used for water collection. Alternatively, water may be collected from several sites and composited.

2.6 Sampling Plan for the Disposal Site

The sediments that are to be dredged occupy a three-dimensional space, and the management units used to divide the dredging area are therefore three-dimensional. The disposal site, on the other hand, is only two-dimensional from a 404(b)(1) evaluation point-of-view. When we compare the sediments from the disposal site to the dredged material, we are comparing the existing sediment surface of the disposal site to a proposed future sediment surface, covered by the dredged material. For this reason, the disposal site should always be sampled with a grab sampler.

The homogeneity of sediments at the disposal site may be less predictable than those at the dredging area. It is therefore advisable that a number of grabs be collected for visual inspection before collecting the samples to be kept for analyses. As stated above, care must be exercised in collecting grab samples to avoid the loss of fine-grained sediments and the introduction of sampling bias. In many areas of the nearshore lake, sediments may be more compacted and consolidated than the sediments in the dredging area. As a result, sample recovery may be poor. The use of different sampling equipment at the dredging area and disposal site may be considered to overcome this type of problem.

It is not appropriate to divide the disposal site into management units, since the term has no meaning here. The number and distribution of samples collected at the disposal site is dependent on the homogeneity of the sediments and the importance of accounting for the natural variability of sediments at the disposal site by the evaluator. For most contaminant determinations, the disposal site is represented a single, composite sample. Where there is considerable heterogeneity in surficial sediments at a disposal site, a single composite sample may not reflect this variability. In order to capture this variability, at least three samples would be needed. If a multiple disposal-site sediment is to be utilized, the evaluator should coordinate with the appropriate agencies in advance as to how the disposal site sediment results will be treated statistically.

The location of sediment sample(s) within the disposal site need not be highly systematic, but care should be taken to avoid non-representative samples. In most cases, the disposal site will be in the nearshore lake. In these areas, the positioning of the sampling vessel may be approximate and maintaining the vessel at a fixed location for extended periods difficult. Using a marker buoy to designate the center of the reference site, samples can be collected at distances and bearings from the marker.

2.7 Sampling Plan Documentation

A written plan for sediment sampling should be prepared and should include the following information:

- map of area to be dredged showing the delineation of management units, proposed sampling locations, and bathymetry,
- rationale for management unit delineation,
- map of disposal site showing proposed sampling locations,
- proposed sampling methods and equipment,
- proposed supporting equipment, vessels, and methods for positioning laterally and vertically,
- proposed logistics for access/mobilization,
- proposed sample compositing, handling and transport,
- identify personnel and contractors who will implement sampling and/or provide equipment,
- QC/QA provisions, and
- health and safety provisions.

This sampling plan can be used for a number of project purposes, including:

- interagency coordination,
- scope of work for contract or in-house,
- part of the Quality Assurance Project Plan (QAPP), and
- part of final report on sediment sampling and analysis.

The sampling plan should be one of the first documents used to initiate interagency coordination for a proposed dredging/disposal project. Without a comprehensive sampling plan, other agencies would not be able to provide comments prior to sampling or adequately evaluate the results upon completion.

The sampling plan will be the scope of work for those who are to implement the sampling, whether through contract or with in-house labor. The sampling plan may prepared as part of a larger document which covers both sampling and laboratory analysis. This is advantageous if the entire effort is to be performed by a single contractor.

The sampling plan is an integral part of the Quality Assurance Project Plan (QAPP), as discussed in Appendix F. The field manager who directs the execution of the sampling program must have read, understood, and signed the QAPP before initiating sampling.

Finally, any sampling program must be flexible to allow for changes based on field conditions. Sampling locations are often changed in the field, and any modifications to the plan should be documented. The plan, along with all field notes or logs should become a part of the final report of sampling and testing.

2.8 Coordination

Interagency coordination on sediment sampling, testing and evaluation should begin as early in the planning process as possible. Coordination during Tier 1 can help identify additional historic sediment data, sources of contamination, and contaminants of concern. Coordination during the development of sampling plans will assure that all agencies understand the reasoning behind the plan, promote cooperative sampling efforts, and reduce the potential for disagreements over the interpretation.

Project proponents are encouraged to use the written sampling plan, discussed in section 2.7, as a basis for coordination with Federal and state agencies prior to field sampling. Given the potential costs of having to repeat sampling and analysis, and the consequences of delays to project schedules, proponents of dredging projects take a serious risk in proceeding with sediment sampling without adequate interagency coordination.

3. SAMPLING EQUIPMENT

There are three types of equipment generally needed to collect sediment samples: a sampler, a mechanism for holding, driving or lifting the sampler, and a floating platform to work from. Sediment sampling can be as simple as scooping a shovel into a shallow creek by hand or as complex as driving Teflon lined Shelby tubes from a truck-mounted drill rig on a spud barge in 25 feet of water. The size of a sampling operation can be one person or a crew of four or five. Equipment costs can range from nothing to $10,000 per day. This section will discuss the available equipment for sediment sampling and provide guidance on where it may be appropriate.

3.1 Sediment Samplers

There are two basic types of sediment samplers; grab samplers and core samplers. Both types of sampling devices can vary considerably in size and degree of difficulty in deployment. The selection of which type and size of sampling device is, like other aspects of the sampling plan, project-specific. The features of sediment samplers commonly used in the Great Lakes are summarized on table D-1.

Table D-1. Features of Sediment Sampling Equipment

Sampler Type	Applicability	Penetration and Recovery	Sample Volume[1]	Supporting Equipment	Cost (new)
Hand held grab	Surface grabs in shallow depths, all sediments	Penetration controllable, recovery usually good	<2 liters	None, except w/ divers	
Drag line	Surface grabs in shallow depths, hard or compacted sediments	Shallow penetration	<1 liter	Small boat	
Small dredge	Surface grabs in all depths, all sediments	Penetration and recovery vary with sediment	1-2 liters	Small boat, winch	$200-700
Clamshell bucket	Surface grabs in all depths, all sediments	Penetration of 1' or more, even in compacted sediment	>100 liters	Floating plant, crane	
Hand held corer	Cores in shallow depths, soft sediments	Penetration controllable, recovery variable	1-2 liters	Pontoon boat or barge	
Gravity corer	Cores in all depths, soft sediments	Penetration and recovery vary with sediment	1-2 liters	Small boat with winch	
Box core	Short cores in all depths, all sediments	Shallow penetration, recovery usually good	variable	Boat with winch	
Vibracore	Cores is depths less than 30', soft sediment	Penetration controllable, recovery usually good	variable	Floating plant & drill rig	
Split spoon	Cores in depths less than 30', all sediments	Penetration controllable, recovery variable	1-2 liters	Floating plant & drill rig	
Piston tube	Cores in depths less than 30', all sediments	Penetration controllable, recovery good.	1-3 liters	Floating plant & drill rig	

[1]Volume of sampler with good recovery.

3.1.1 Sampler selection

In comparing the different types of grab and core samplers, and selecting the one most appropriate for a particular application, the primary factors to consider are:

- supporting equipment requirements,
- physical restrictions,
- depth of sample (penetration)
- sample recovery,
- sample bias,
- sampler material, and
- sample volume.

Supporting equipment requirements: The type and size of supporting equipment needed for sampler operation may determine the feasibility of operation, and will greatly affect sampling costs. Supporting equipment are described further in section 3.2.

Physical restrictions: Physical restrictions which might limit the operation of a sampler (and supporting equipment) include the water depths, currents/tidal/wave conditions, and sediment characteristics.

Sample penetration: The depth from which the sample is collected is determined by the depth of sampler penetration. For some samplers, this depth may be controlled. With other samplers, this depth is dependent on the type and size of sampler used, water depth, and consistency (soft/hard) of the bottom sediments.

Sample recovery: Recovery is an indication of how much sample is present in the sampler, and is usually estimated as a percentage, with a full sampler being 100% recovery. Poor recovery can result from the sampler failing to close properly or sample loss during lifting.

Sample bias: Sample bias is a significant concern, especially for samples that have poor recovery. As the sampler is pulled up, sample may be lost to the water column through the sampler screen or if the sampler is not fully closed. Fine sediment particles are most susceptible to loss, and this preferential loss may bias the sample.

Sampler materials: Consideration must be given to the contaminating properties of the sampling devices themselves. Often there will be conflicting requirements for different test parameters. The general rule is that for metals analysis, samples should not contact metal samplers or containers and for trace organic analyses, samples should not contact any plastics. These general rules are not always practical to apply and may not be necessary for the data quality objectives of 404(b)(1) evaluations.

Since the 404(b)(1) contaminant determination does not rely on the mere presence of contaminants (which may have come from sampler materials) for final decisionmaking, samplers made of (or lined with) stainless steel, aluminum, Teflon, and high density polyethylene (HDPE) plastics should be acceptable for use. Samplers made of other material may also be suitable if the sample not in contact with the device can be selectively removed. All samples should be collected with the same sampler materials where possible. The use of different samplers for different analysis might complicate the interpretation of results.

Sample volume: The volume of sediment needed will vary with the test requirements. A summary of the sample volumes required for the tests described in the Great Lakes Dredged Material Testing and Evaluation Manual is provided on table D-2. The approximate volume of sample provided by full (100% recovery) samplers are listed on table D-1.

Table D-2. Sample Volumes Required for Analyses

Analyses	Sample Volume	
	Sediment	Water[1]
Sieve analysis	0.5 liter	
Hydrometer analysis	0.5 liter	
Bulk chemistry[2]	0.5 liter	
Elutriate	1 liter	4 liters
Column settling test	40 liters	
Water column toxicity		
Whole sediment toxicity		
Bioaccumulation		

[1] Site water required for elutriate test. Other tests can use laboratory water.
[2] Volume shown for analysis of metals, nutrients, PCBs and PAHs. Larger volumes may be needed for analysis of other parameters or lower detection limits.

3.1.2 Grab samplers

A grab sampler is any type of device that collects a disturbed sample at the sediment-water interface. A "disturbed" sample is one that has lost its vertical and lateral integrity and can't be subdivided into meaningful layers or fractions (as can some core samples). Grab samples are collected at the sediment surface, and represent the depth of sediment penetrated by the sampler.

Hand-held samplers: Shovels, trowels, and buckets can be used to collect sediment samples by hand in shallow streams. Sediment sampling in deeper waters by divers using hand-held samplers is becoming a fairly common practice. Hand-held grab samplers are inexpensive, require little or no supporting equipment, can control sample penetration to a limited extent, and generally have good recovery.

Drag-line samplers: Samplers have been developed which are operated by dragging along the bottom. These type of samplers include bottom dredges equipped with nets for collecting biological materials. A pipe dredge is a metal tube, about 6" in diameter and 18" long, which is used to collect surface samples from hard, rocky surfaces. This type of sampler may be more suitable for the disposal site than the dredged material.

Small dredge samplers: There are a number of small, light-weight dredge samplers available from commercial sources. Comparisons of these types of grab samplers are provided by Mudrock and MacKnight (1991), ASTM (1984), Elliott and Drake (1981) and Sly (1969). Some of these samplers come in several sizes. For example, the Ponar petite sampler (6" x 6") weighs about 25 pounds and can be operated by hand from a small boat. The Ponar (9" x 9"), shown on figure D-2, weighs about 50 pounds and needs a boat with a winch and cable for operation.

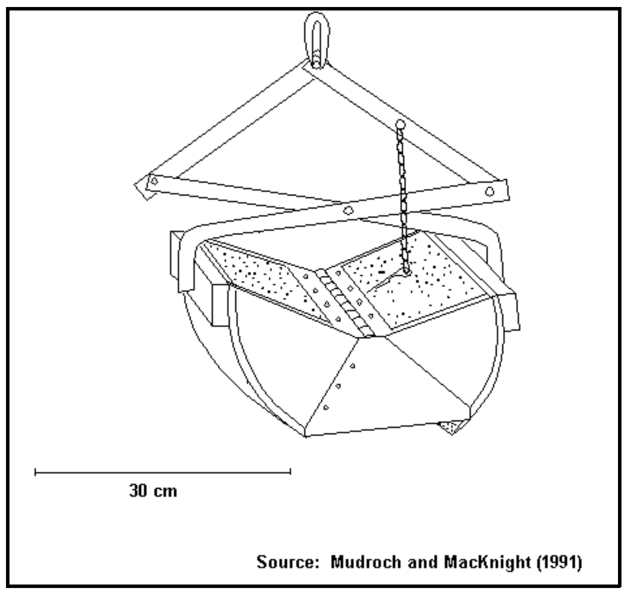

Figure D-2. Ponar Dredge Sampler

Most small dredge samplers will only penetrate 1-3 inches in sandy sediments. The same sampler might penetrate 6-12 inches in fine-grained sediments that are soft and unconsolidated. Sediments that have a hard, consolidated surface often give poor recovery and may be subject to sample bias. Soft sediments will often yield 100% recovery with grab samplers. Dredge samplers typically cost $200-700.

Clamshell dredge bucket: Although not designed for sampling, commercial clamshell dredges (0.5-3 cubic yard bucket) can also be used for collecting sediment samples. Clamshell buckets are operated by a crane, and require a sizable floating plant (figure D-3). The bucket is typically lowered onto the deck of the floating plant, and sample(s) removed with shovels or trowels. A crane operated clamshell bucket can penetrate several feet, even into compacted sand. Recovery is usually good. Sample bias can be avoided by compositing several subsamples from different areas within the bucket grab.

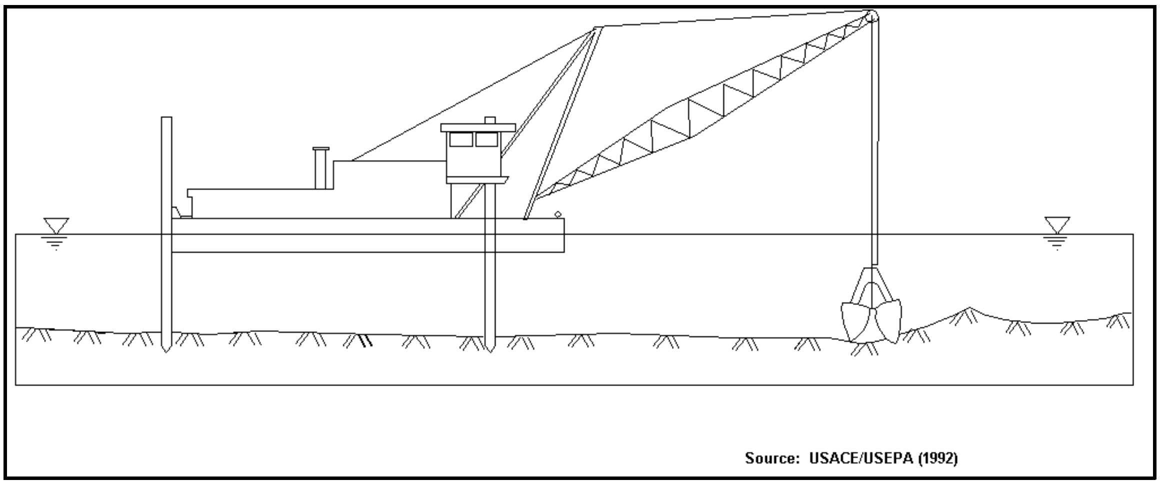

Figure D-3. Clamshell Dredge on Spud Barge

The clamshell dredge bucket will provide far more sample than is necessary for sediment contaminant testing for 404(b)(1) evaluations. Multi-purpose sediment sampling may require large volumes. Several hundred gallons of sediment have been collected with clamshell dredges for testing and evaluation for confined disposal and treatability studies on contaminated sediments.

3.1.3 Core samplers

A core sampler is a device that extracts a vertical cylinder of sediments of some length. The core sample may or may not fully retain its integrity. Some types of core samplers are designed to assure the least loss of vertical integrity. For others, some loss of integrity is acceptable. Core sampling equipment that may be used include equipment designed for geotechnical exploration and well construction. In addition, there are several pieces of equipment developed specifically for sampling bottom sediments. The features of the most commonly used core samplers are summarized on table D-1.

Hand-held samplers: Hand-held core samplers are available from commercial sources. Many laboratories and contractors have fabricated core sampling equipment from lengths of pipe. For some applications, this type of improvised sampler is quite acceptable. The pipe material used should be selected to avoid sample contamination (see discussion in section 3.1.1). Tubes or sleeves of noncontaminating materials are available for commercial corers.

The hand-held core sampler is pushed into the sediments to the desired depth, withdrawn, and the sediments pushed out with a rod, or the pipe or tube cut to expose the sample for removal. Hand-held samplers can by used by wading in shallow streams or by divers. Hand-held samplers should not be operated from a boat, since it is generally necessary that the operator stand to drive and withdraw the sampler. Vessels with a flat deck, such as a small barge, pontoon boat or floating plant are needed to safely support the sampler.

The operation of a hand-held core sampler is limited by the depth of water, sediment characteristics, and sediment thickness. For total depths (water + sediment) greater than 10-15 feet, the length of the sampler becomes unwieldy for hand operation. Hand-held cores can be easily pushed through soft sediments, but are not recommended for consolidated materials. Recovery with hand-held core samplers is variable. A catcher is typically used at the front end of the core to hold the sediments in-place as the sampler is withdrawn. Samplers with an open end can also be "capped" by driving them through the soft sediments and a few inches into hard clay or sand.

The bias of a core sample is related to its recovery. A sample with poor recovery may have preferentially lost sediment from the leading (deeper) end. Hand-held cores may loose some vertical integrity, as sediments may be compressed in the core. A 3-foot drive may yield only 2 feet of sample, even with good recovery. Consequently, hand-held cores are acceptable for vertically composited samples, but vertical subdivision may not reflect the true elevation of sub-samples.

Gravity core samplers: There are a number of commercially available core samplers that are deployed on a cable and penetrate the bottom sediments with only the force of gravity. A summary of available corers is provided by Mudroch and MacKnight (1991) and Sly (1969). Most corers have small diameters (1-2") with variable lengths, and come equipped with additional weights and a catcher. Some have vanes or stabilizing fins. A typical gravity corer is shown on figure D-4.

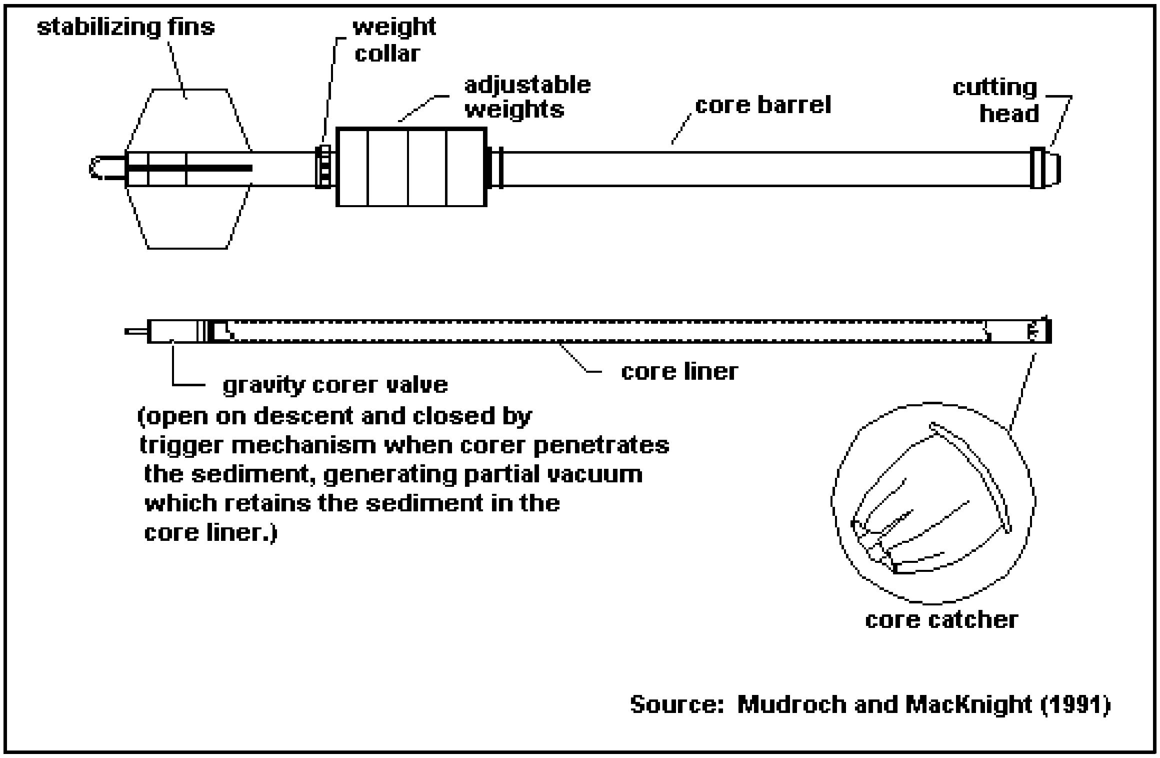

Figure D-4. Typical Gravity Core Sampler

Small gravity corers can be operated from small and medium sized boats by hand or with a winch. Best performance is found where the corer is allowed to freefall between 2-3 meters (Mudroch and MacKnight 1991). Gravity corers can collect up to 2 meters of soft sediments, and are not suitable for hard or consolidated sediments. Sample recovery and vertical integrity are variable.

Box core sampler: Box corers are gravity corers designed for collecting large rectangular sediment cores of the upper 50 cm sediment layer (Mudroch and MacKnight 1991). A typical box corer is shown on figure D-5. Small box corers, weighing about 30 pounds, are equipped with additional weights (up to 100 pounds) to improve penetration. Much larger box corers, up to 2m x 2m and weighing 800 Kg, have been

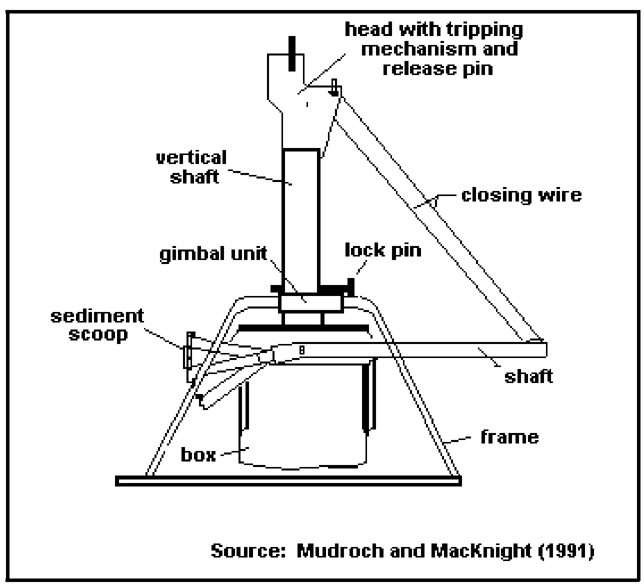

Figure D-5. Box Core Sampler

fabricated (Mudroch and MacKnight 1991). The corer is lowered to the bottom by acable with little freefall, and the triggered with a messenger. Small box corers may be operated from a boat with a winch.

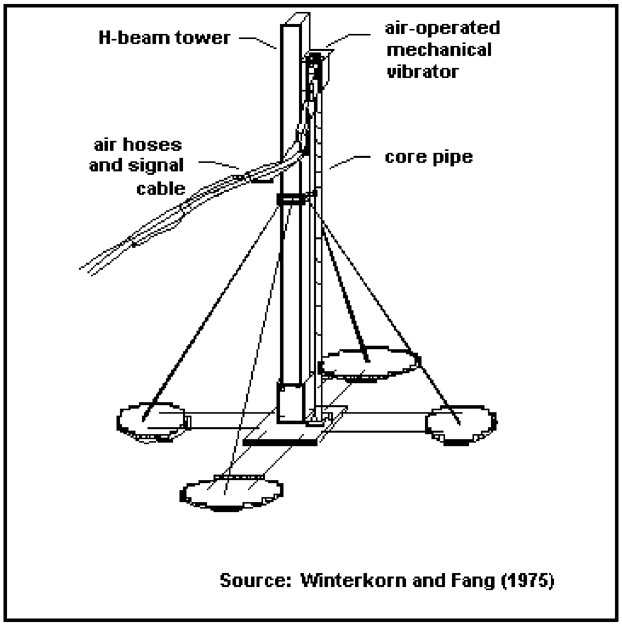

Figure D-6. Vibracore

Vibracore: The vibracore is a long continuous tube that is driven into the sediment using vibrating action, typically of a pneumatic impactor, as shown on figure D-6. The entire core is withdrawn, at which point the entire sample can be extruded and subdivided, or the tube may be cut into segments for sample extraction later. Guidance on the fabrication of a vibracore from readily available components is available in Smith and Clausner (1993). The vibracore can be operated from a small floating plant or barge with a tripod or small derrick and winch to assist in raising and lowering. Vibracores are typically 2-4 inches in diameter. Sample lengths up to 20 feet have been sucessfully removed from sites in Great Lakes tributaries.

The vibracore is only suitable for unconsolidated sediments, particularly sandy sediments. They can not penetrate most consolidated or coarse materials. Cores can be equipped with a catcher or the tube driven into a layer of compacted material, which forms a "cap" at the bottom. The vibration of the tube has been known to consolidate the sample. The vertical integrity of vibracore samples may be disturbed. Vibracores are well suited for the collection of samples to be vertically composited.

Split-spoon: The split-spoon sampler is basic equipment for geotechnical exploration of unconsolidated soils. The sampler is a metal cylinder which is divided in half, lengthwise, as shown on figure D-7. The two halves of the spoon are held together by small pieces of threaded pipe at each end. An open cap, with a catcher is screwed on the tip. The sampler is attached to lengths of steel rod and driven into the sediments with a hammer or weight. After the sampler is withdrawn, the front and rear end pieces are unscrewed, the sampler opened, and the sample removed with a spoon.

Split-spoon samplers can be used for most types of sediments, including consolidated sand and clay. Recovery is variable, sometimes poorer with soft, fine-grained sediments. Split-spoon samplers are typically 2-3 inches in diameter, and available in lengths from 2-5 feet. Successive vertical samples can be taken by driving casing (typically a 5-inch pipe) and cleaning out the drill hole between samples, as shown in figure D-7. The vertical integrity with of an individual split-spoon sample is variable, but a vertically composited sample can be obtained between two elevations with accuracy.

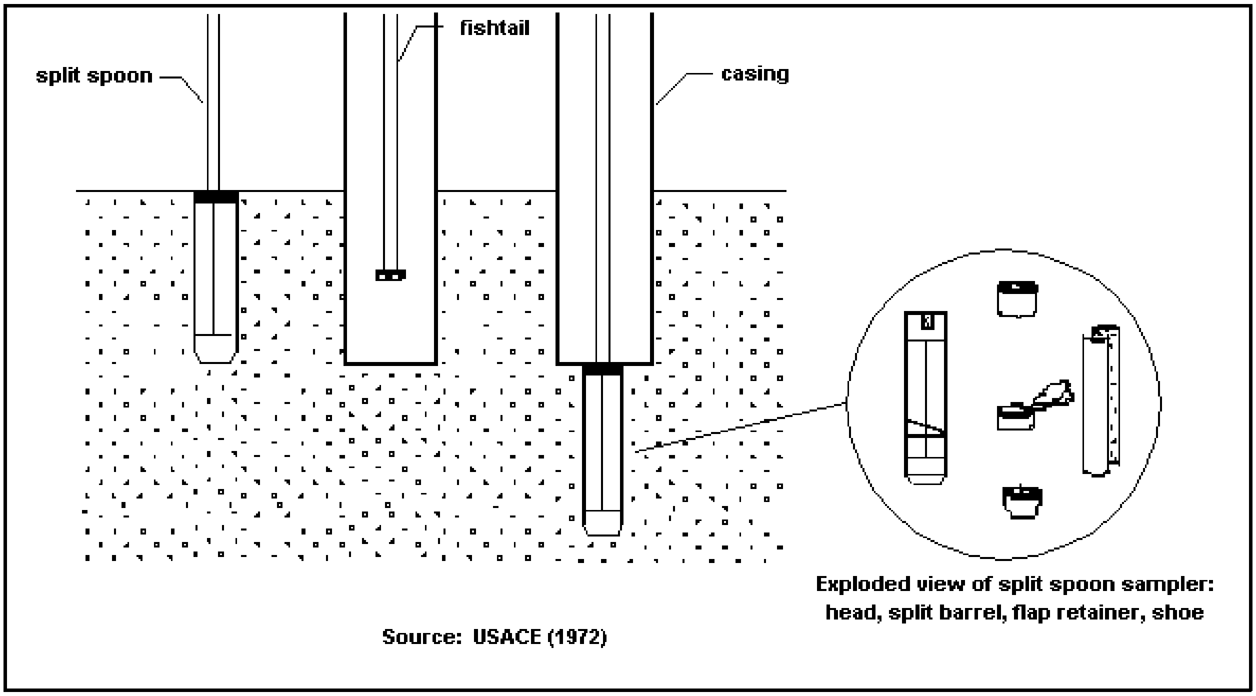

Figure D-7. Split-Spoon Sampler

Piston samplers: There are a number of samplers that use a thin metal tube that is extended forward under hydraulic force. These include the thin-wall stationary piston sampler, Lowe-Acker stationary piston sampler, and the Osterberg (as shown on figure D-8) and McClelland piston samplers (Winterkorn and Fang 1975). Piston samplers can be operated from a variety of drill rigs on small floating plants. The sampler, with tube retracted, is attached to a steel rod and pushed into the sediments to the desired starting depth. The hydraulic force is applied (water pump) and the tube extended. The sediments in the tube are held in a partial vacuum, and the assembly withdrawn. The tube is removed and the sediments extracted.

Piston samplers are suitable for soft, unconsolidated sediments. The sampler can penetrate some consolidated fine-grained sediments, but not coarse materials. Recovery with soft, fine-grained sediments is excellent. Sampler tubes are

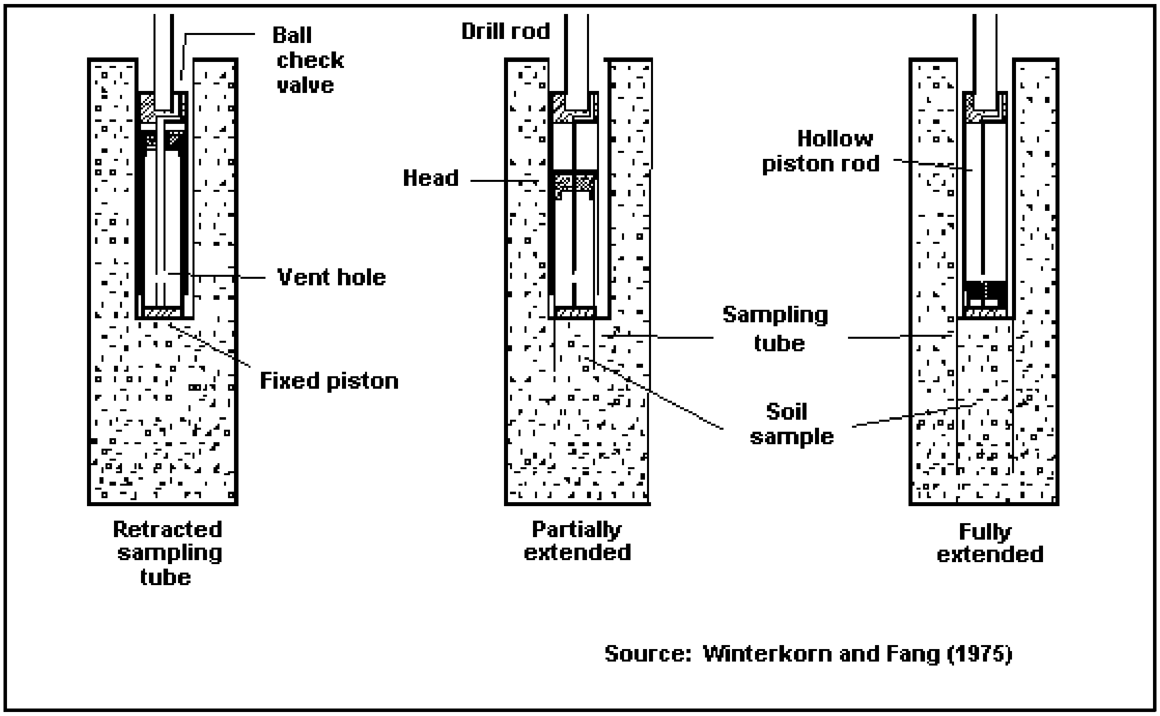

Figure D-8. Piston Sampler

typically 3-4 inches in diameter and 3 feet long. The vertical integrity of individual samples is variable, but a vertically composited sample can be obtained between two elevations with accuracy, and without the need for casing.

3.2 Supporting Equipment

The size and complexity of supporting equipment varies for the different samplers. Most supporting equipment requires experienced operators. Some require a crew of several persons. Information will be provided on marine equipment, cranes and drilling rigs. Information on marine equipment, cranes and drilling rigs needed to support sediment sampling activities is summarized on table D-3.

3.2.1 Marine equipment

Almost every size and type of boat, barge, and floating platform has been used for sediment sampling at one time or another. The suitability of a boat or floating platform is determined by the size and operating requirements of the sampler and the physical restrictions of the sampling site(s). These site restrictions include:

- water depth,
- wave/tidal/current conditions, and
- accessibility.

Table D-3. Supporting Equipment for Sediment Sampling

Equipment	Applicability	Crew[1]	Cost[2] ($/day)
Small boat (<16 ft)	For use with handheld or winch-operated dredge, box, or gravity core samplers. Suitable for shallow conditions.	Operator (1)	$200-500
Large boat	For use with handheld or winch-operated dredge, box or gravity core samplers. Suitable for near-shore conditions.	Operator and mate (1-2)	$400-1,000
Pontoon boat	For use with handheld core, dredge, box and gravity core samplers. Suitable for calm waters only.	Operator (1)	$400-800
Collapsible drill rig	For use with split spoon or piston samplers on small barge.	Driller and helper (2)	$1,000-2,000
Truck-mounted drill rig	For use with split spoon or piton samplers on larger barge.	Driller and helper (2)	$1,000-2,000
Skid-mounted drill rig	For use with split spoon or piston samplers. Suitable for calm waters and moderate depths.	Driller and helper (2)	$1,000-2,000
Crane, 20-ton	For use with clamshell dredge bucket, to mobilize sectional barge, or to lift spuds.	Operator (1)	$500-1,500
Small sectional barge	For use with Collapsible drill rig. May require supporting vessel for propulsion. Suitable for calm waters and moderate depths.	Operator (1)	$400-1,000
Spud barge	For use with truck-mounted drill rig or crane. May require supporting vessel. Suitable for near-shore and depths to 30 feet.	Operator and mate (2)	$1,000-3,000

[1] Crew size of combined equipment may be reduced if crew perform multiple duties. For example, if barge operator also operates crane.

[2] Costs are for planning purposes only.

Equipment availability and cost may also be important factors in the selection of supporting equipment. For example, if a marine construction contractor is already mobilized near the sampling site, it may be more cost efficient to rent the contractor's equipment, even though it is larger than needed for sampler operation. In all cases, safety must be the overriding consideration in the selection of supporting marine equipment.

Boats: Small boats with outboard motors may be suitable for supporting some small clamshell dredge samplers and drag-line samplers in small tributaries and nearshore waters. Larger boats, with an electric or hand-crank winch are suitable for supporting larger clamshell dredge samplers, small gravity core samplers, and small box corers. Pontoon boats are suitable for supporting all grab samplers (except crane-operated clamshell buckets), hand-held cores and gravity and small box cores.

Sampling boats should generally be anchored at stations as best possible for safety and sample collection proficiency reasons. Some grab samplers will not function properly when drift causes them to strike the bottom on an angle less than perpendicular. Anchoring is an especially important safety consideration when divers are operating the sampling devices.

A qualified boat operator and sampler operator are the minimal crew for most small boats. Larger boats, suitable for work in the lake or large tributaries, may require additional crew members.

Floating platforms: A variety of barges, skiffs and marine floating plants can be used for supporting larger sampling equipment. The selection must consider the size and weight of other supporting equipment (crane or drill rig) and the need to be stationary. Some barges and skiffs are self propelled, others require boats or small tugboats for propulsion. Crew sizes range from two to four.

If core sampling equipment is used, it is necessary to keep the sampler position laterally stationary. There are only a few methods of holding a barge, skiff, or floating plant in place at the sampling site. Anchoring is not always reliable in keeping a large vessel in place, except under very calm water conditions. If the sampling location is immediately next to land, the vessel can be tied to available structures.

The most reliable method of stabilizing a barge, skiff, or floating plant is the use of spuds, as shown on figure D-3. Spuds are long steel posts which are lowered into the sediments, typically at each end of the vessel. Some vessels have spuds which are hydraulically lifted, while others have them lifted with a crane on deck. On some small, sectional, spud barges, the spuds are lifted by hand.

Most small barges and skiffs are transported overland by trailer and moved into and out of the water by a winch or using a crane. Larger barges and floating plants are usually transported to the site by water.

3.2.2 Cranes and drill rigs

Cranes are used to operate clamshell dredge buckets and/or to lift spuds on floating plants. A crane may also be used to place a barge or floating plant into the water.

There are many types of drill rigs used in geotechnical explorations (Winterkorn and Fang 1975), but only the smaller, collapsible varieties shown on figure D-9 have been routinely used for dredged material sampling at sites on the Great Lakes. A drill rig is basically a vertical frame or scaffold used to hold long lengths of pipe or core steady as they are lowered, raised, connected and disassembled.

A-frame and tripod drill rig assemblies are small, collapsible, and can be assembled on very small barges. A truck-mounted drill rig, commonly used in drilling potable water supply wells and installing monitoring wells, has a collapsible rig mounted on a truck. Truck-mounted drill rigs can be driven onto barges or floating plants and chained to the deck. Drill rigs can operate through a hole in the barge or floating plant (if available), or over the side. Small drill rigs are typically operated by a driller and a helper (crew of two).

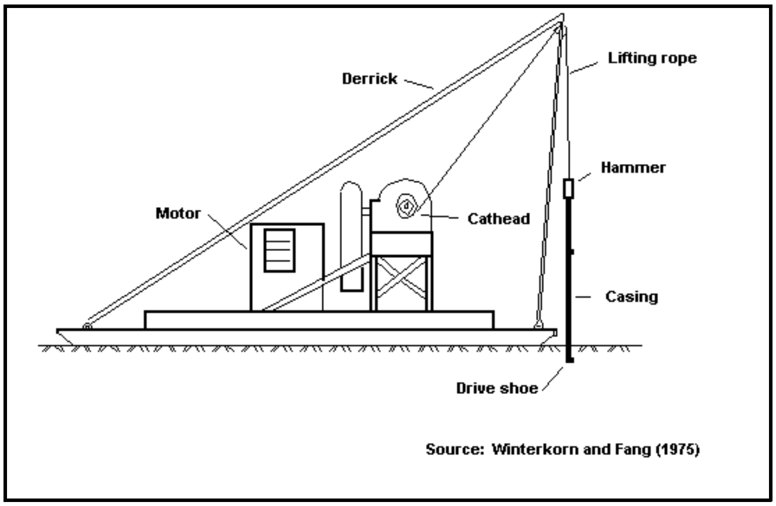

Figure D-9. Collapsible Drill Rig

3.3 Sampling Costs

The primary costs of a sediment sampling program are primarily for labor and supporting equipment. These tend to increase together, as larger equipment generally requires a larger, and more skilled crew. Estimates of the daily rates for supporting equipment (including crew) are shown on table D-3. These rates should only be used for the initial planning of a sampling project, and will vary with the locale and equipment availability.

A significant amount of the cost involved in sediment sampling is the mobilization and demobilization (setup and breakdown) of supporting equipment. The mobilization cost is determined by how far the contractor has to come with his/her equipment. It is not uncommon to have a mobilization cost equal to 1-2 days effort, and demobilization equal to a one day effort.

The rate at which sample collection takes place is project and equipment specific. If sampling locations are far apart, significant time may be spent in relocating equipment. The positioning of sampling locations may also require additional time (see section 4.1). After the site has been reached and positioned properly, grab samples can usually be collected in 5-15 minutes. Core samples of a continuous length can be collected in 15-60 minutes. Core samples collected at three depth intervals might take 1-3 hours. After the sample(s) have been collected, additional time is required to visually inspect and characterize them, and prepare them for storage. It may or may not be feasible to do this on the way to the next station.

For most projects, once the equipment has been mobilized, the cost of collecting additional samples can be relatively inexpensive. The collection of extra samples at planned sampling locations, or at different sampling locations can provide a valuable contingency in the event of sample loss or anomalous sample results. On practice is to collect extra samples and make provisions with the laboratory to store them for a limited time and dispose of them if not needed.

4. GUIDANCE ON FIELD ACTIVITIES

4.1 Location Stationing

4.1.1 Horizontal positioning

The location of a sampling station needs to be determined both horizontally and vertically. The precision of location stationing will vary with the requirements of the sampling plan and site conditions. Depending on requirements and conditions, it may be adequate to position sampling stations visually, without instrumentation, using available landmarks for reference. Generally, this is only appropriate in small rivers or in harbor locations near (<50 feet) land, piers, or breakwaters.

Positioning of stations in larger rivers, open harbors or the nearshore lake should be done using some type of instrumentation. A variety of instruments may be used, including land survey equipment, Loran, and global positioning systems (GPS). Most commercial navigation vessels and larger recreational craft are equipped with Loran, while GPS is becoming more commonly available. If stations are positioned by a dedicated survey team, it will be more cost efficient to have all stations located, and marked with buoys on one day rather than to have the survey team stay for the duration of sediment sampling.

4.1.2 Vertical positioning

Location positioning should include the elevations of the water surface and sediment-water interface. This is especially important for dredging projects. Since sediments are typically dredged to a fixed elevation, a sample collected below this elevation would not be part of the material to be dredged. Water depth can be determined using a lead line, sounding basket, or bathymetric instrumentation. Because all water surfaces fluctuate over time, the water surface elevation must be referenced to an fixed datum.

The accepted elevation datum for the Great Lakes is the International Great Lakes Datum (IGLD), which is referenced to the zero point at Rimouski, Quebec. This datum was adjusted in 1955 and again in 1985 to account for movements of the earth's crust (Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data 1992). Conversions between IGLD 1955 and other elevation datum are summarized on table D-4.

Table D-4. Elevation Conversion Chart

Given	To Find				
	CCD[1]	IGLD 55	MTNY[2]	MSL[3] 1912	MSL 1929
CCD		+578.18	+579.88	+579.91	+579.48
IGLD 55	-578.18		+ 1.70	+ 1.74	+ 1.30
MTNY	-579.88	- 1.70		+ 0.04	- 0.40
MSL 1912	-579.91	- 1.74	- 0.04		- 0.44
MSL 1929	-579.48	- 1.30	+ 0.40	+ 0.44	

[1] Chicago City Datum
[2] Mean Tide New York
[3] Mean Sea Level

Low Water Datum (LWD) are the planes of reference to which most Great Lakes navigation charts are referenced. The LWD elevation reflects the average low water elevation of the individual lakes. The Low Water Datum elevations of each of the Great Lakes referenced to IGLD 55 and IGLD 85 are shown on table D-5.

Table D-5. Low Water Datum for IGLD 85

Lake	IGLD 55 (feet)	IGLD 55 (meters)	IGLD 85 (feet)	IGLD 85 (meters)
Lake Superior	600.0	182.9	601.1	183.2
Lake Michigan	576.8	175.8	577.5	176.0
Lake Huron	576.8	175.8	577.5	176.0
Lake St. Clair	571.7	174.2	572.3	174.4
Lake Erie	568.6	173.3	569.2	173.5
Lake Ontario	242.8	74.0	243.3	74.2

Water surface elevations may be referenced from survey markers installed by the USACE or other agencies, or from fixed structures that have been surveyed and elevations recorded. USACE survey markers are small (3 1/2" diameter) brass plates, placed at locations around authorized navigation projects. Their locations and elevations can be obtained from the appropriate USACE district office. Water levels can be obtained from recording gages maintained at selected sites on the Great Lakes (NOAA 1992a), although these are not as representative as "on-site" measurements and should be used only as a last resort.

Bridges are often used to reference water level elevations. The elevation of low steel, the lowest point of the bridge span, is available for many bridges from city or state highway departments, railroads, port authorities, and the USACE. Bridge clearances, to the nearest foot above LWD, are also published in the "Coast Pilot" (NOAA 1992b).

4.2 Logistics

Pre-planning is necessary to assure a successful sediment sampling project. This planning should address several logistical features, including access locations, sampling sequence, contingency, and overall scheduling.

Access to sampling locations is not usually a problem in and around authorized navigation channels. Launch ramps for boats and small floating plants are available at most lakefront and riverside marinas and local, State and Federal parks. Larger boats and floating plants may need a secure docking area for mobilizing equipment. At waterways away from authorized navigation channels, access may be a problem. Bridges, pipeline crossings and other obstructions may necessitate that sampling vessels be remobilized several times. In some cases, easements may have to be obtained from landowners to gain access. Access locations should be identified and inspected during the planning of a sediment sampling project to assure they will be available and feasible.

In many rivers and harbors around the Great Lakes, the levels of sediment contamination increase as one proceeds upstream from the nearshore lake. One way to help minimize cross-contamination of sampling gear is by scheduling the sampling stations so that the most contaminated areas are sampled last. While this approach will not eliminate the need for decontaminating equipment between samples, it will reduce the potential for cross contamination.

Almost all sampling plans will be subject to unforeseen complications. Many of these problems can be avoided by assuming the plan is imperfect from the start and preparing contingencies. The most common problems are equipment failure and bad weather. If possible, it is advisable to carry a spare for any equipment subject to failure. The location and phone numbers of sources for parts or equipment repair should readily available.

Storm events can delay or interrupt sampling, so contingencies need to be arranged with both the sampling team, delivery service, and the laboratories. All contingent field changes should either be identified in the sampling plan or at the very least, a chain of command should be defined by which clear responsibility is assigned for each such decision.

Scheduling requires understanding of the operational capability of the laboratories. Sampling tends to occur on weekdays, and delivery or sample holding over a weekend can be problematic, especially since the material needs to be refrigerated. The delivery of samples at a rate that overwhelms the laboratory is also not desirable, because holding times are extended. However, these types of timing problems may not always be avoidable, depending upon the cost of sampling equipment mobilization and other such factors.

4.3 Sample Collection

There are many reasons why slow methodical collection protocols are best, not the least of which is safety. Taking extra time to be sure that the vessel is on station, the proper sampling device is outfitted with the correct attachments, the correct jars and labels are being used, the proper methods of sample splitting and mixing are being deployed, and all activity and conditions are fully documented in the sampling log can save having to repeat these activities.

Because of the complexity associated with sediment sampling, it is always good practice to assign all team members specialized responsibilities. Further, a single lead team member should work with the vessel operator and oversee all sampling and handling activities. This team leader is usually also responsible for documenting the field work in the sampling log.

A field log should always be prepared to describe the conditions and events of the sediment sampling project. The field log used by the USACE for geotechnical borings (ENG Form 1836) is provided as Attachment D-1. An example of a field log which is more appropriate to grab sampling is provided at Attachment D-2. Field logs should document conditions of the sampling location, elevations of the water and sediment surfaces, information about the sampling equipment and sample recovery. The logs should also record the physical appearance of the sediment sampled. Categories of sediment characteristics are listed on table D-6. Photographs of the sample are another way to document physical appearance.

All sampling and field measurement equipment should be checked and tested before leaving shore. Sampling equipment (the parts which contact the sediment sample) should be cleaned before the sampling project and in-between project samples. Recommended pre-project cleaning procedures are as follows:

- wash with non-phosphate detergent,
- triple rinse with distilled water,
- rinse with acetone,
- rinse with reagent grade hexane, and
- air dry.

In the field, sampling equipment should be cleaned between samples to avoid cross-contamination. Although the above cleaning procedures are appropriate, the use of acetone and hexane on some sampling vessels or with some sampling equipment may be infeasible or present safety problems. The following are minimum cleaning procedures between samples:

- brush wash with site water, and
- rinse with distilled water.

Table D-6. Categories of Sediment Characteristics

Type	Size or Characteristic
Inorganic components[1]	
Cobbles	75 to 300 mm (3 to 12")
Gravel	4.75 to 75 mm (3/16 to 3")
Sand	0.075 to 4.75 mm
Silt	0.005 to 0.075 mm in diameter
Clay	< 0.005 mm; smooth, slick feeling when rubbed between fingers
Organic Components[2]	
Detritus	accumulated wood, sticks, and other undecayed coarse plant materials
Fibrous peat	partially decomposed plant remains; parts of plants readily distinguishable
Pulpy peat	very finely divided plant remains; parts of plants not distinguishable; varies in color from green to brown; varies greatly in consistency-often semi-fluid
Muck	black, finely divided organic matter; completely decomposed

[1] Unified Soil Classification System
[2] USEPA (1973)

4.4 Sample Handling and Containers

Sediments should be removed from samplers and handled using non-contaminating equipment. In most cases, stainless steel spoons and bowls which have been cleaned in the same manner as the sampler are appropriate. One very common mistake made during sediment sample handling is pouring off "excess water". This water, and the fine particulates in suspension, are part of the sample. Discarding it may bias the sample.

The homogenization, or mixing of a sediment sample in the field is not necessary for most circumstances. If the sediment sample is to be analyzed by a single laboratory, homogenization can be conducted at the lab under more controlled conditions. In cases where the sample is to be divided into two or more containers for shipment to different laboratories, sample homogenization can be conducted in the field, or the entire sample can be shipped to one laboratory, where the sample is homogenized and aliquots are shipped to other labs. Laboratories should be given specific instructions about sample homogenization and notified that water in sample containers should not be discarded, but homogenized with the sample.

Homogenization in the field may be appropriate where the volume of sample collected is far greater than the volume to be transported, and the intent is to have the sample placed in the containers representative of the whole sample collected. In this case, slow and smooth mixing techniques should be used. Overmixing may cause spillage and the aeration of the sediment sample which may alter the sediment chemistry. The larger the volume of a sediment sample, the more difficult it will be to mix the sample in the field. Samples must be protected from external sources of contamination, such as boat splash and fuel and lubricants, during handling.

Sediment samples should be placed into containers and stored at 4^{o} C as rapidly after collection as possible. Containers should be filled to the top with the sample, leaving no head space.

Containers for sediment samples should be made of clean, non-contaminating materials. If the sediment sample were solely for a specific type of chemical analyses, it might be appropriate to chose the container materials which avoids contamination or bias. Since most sediment samples for 404(b)(1) determinations are intended for a variety of analyses, and because of the difficulty in assuring that sub-samples prepared in the field are homogeneous, it is recommended that samples be contained in one type of container for transport to the laboratory, where the sample can be homogenized and sub-divided.

Recommended container materials include wide-mouth glass jars with Teflon-lined caps and high density polyethylene (HDPE) plastic buckets with lids. Each has its advantages and disadvantages. Glass jars are available in a variety of sizes, and are most suitable for smaller sample volumes (1-4 liters) needed for bulk chemistry, grain size analysis and elutriate tests. Glass jars require considerable care in packing and transport, and can break despite the best precautions. HDPE plastic containers are available in small and large sizes, including 5-gallon tubs which are well suited to the large volume samples needed for toxicity, bioaccumulation and column settling tests. Sample containers and lids should be cleaned as follows:

- wash with acid (chromic or HCl),
- rinse with distilled water,
- wash with non-phosphate detergent,
- triple rinse with distilled water,
- rinse with acetone,
- rinse with reagent grade hexane, and
- air dry.

New containers from laboratory supply companies are generally cleaned to the above or better specifications. New containers from bulk supply companies may need to be cleaned before use.

Sample containers must be identified unambiguously, and a precise sample labeling and coding system should be developed prior to field work to avoid costly mistakes. It is recommended that sampling jars and vessels be pre-labelled, as field conditions are often wet and bumpy, and labels can become scribed indelibly. Labels must be able to withstand the conditions of transport and storage without deterioration or becoming loose. Labels on glass jars stored in wet ice have been known to become "unglued" in transport. To prevent such problems, glass jars may be placed into plastic bags and sealed (this also helps control the mess if a jar breaks in transport). Plastic containers can be marked with indelible pens or markers in addition to regular labels, as a safeguard. Examples of labels used by the USACE for soil samples and by USACE division laboratories are provided at Attachment D-3.

4.5 Sample Transport

Sample containers should be packaged for transport in a manner that maintains them at 4^{o} C and protects them from breakage or spillage. A variety of packing materials and containers are available specifically for the transport of environmental samples. Considering the costs of sample collection and analyses, these materials are a sound investment.

There are a number of transport modes for sediment and water samples. Most overnight transport carriers will accept environmental samples providing they are in secure containers. Some carriers will not accept wet ice, and most will not accept dry ice. Packaged refrigerants ("blue ice") are accepted by most carriers. When large samples are collected (several 5-gallon tubs), it may be more cost effective to lease a refrigerated truck or contract a specialized carrier. The temperature of samples should be measured and recorded at the time of arrival in the laboratory.

Procedures for documenting chain-of-custody for dredged material samples are recommended. An example of a USACE chain-of-custody record for potentially hazardous samples is provided at Attachment D-4.

4.6 Health and Safety

Worker health and safety must be a paramount consideration during all sediment sampling activities. USACE contractors are required to follow the procedures of the Safety and Health Requirements Manual (USACE 1987). Corps districts require that its boat operators have completed certified training from the U.S. Coast Guard and that its divers be certified and follow the procedures in the U.S. Navy Diving Manuals (U.S. Navy 1988).

Most rivers have numerous crossings by utilities buried beneath the river bottom, and in some cases exposed on the sediment surface. These include water and sewer pipelines, gas and petrochemical pipelines, electrical and telecommunucations cables. Navigation charts typically show utility crossings, but are not always complete or up-to-date. Developers of sediment sampling plans should contact the appropriate utilities to confirm the presence and locations of crossings, especially when any drilling is planned.

Each crew member should be fully outfitted with appropriate safety equipment and properly fitted clothing. Provisions should also be made for staff to clean-up during and after sampling. Soaps, brushes, sponges, water and change of clothing should be available when appropriate. Rain and weather protective clothing and life vests are always appropriate for on-board stowage.

In general, sediments that are being considered for open-water disposal will not contain sufficient levels of contamination to require sophisticated personnel protective equipment (PPE). Workers should avoid any dermal contact with sediments and all sampling equipment should be handled with protective gloves. With more contaminated sediments, disposable Tyvec[c] clothing should be worn.

Pre-planning for sediment sampling should identify the location and telephone numbers of emergency assistance, including police, Coast Guard, marine assistance, and hospital emergency service. This information should be readily available to the entire field crew.

4.7 Environmental compliance

The USACE has issued nationwide permits under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act for minor dredging and discharge of quantities less than 25 cubic yards (Federal Register, November 21, 1991). In most instances, sediment sampling for testing purposes will be covered by these nationwide permits, and no separate permits required under these authorities. In cases where sampling is conducted in waterways adjacent to private property, the rights of riparian owners should be considered.

The disposal of field generated waste, other than excess sediment samples, are regulated by Federal, State and local laws and regulations.

5. QUALITY ASSURANCE/QUALITY CONTROL

Most of the specific quality control procedures that are appropriate for sediment sampling and handling have been described in this appendix. These included recommended sampling protocols, methods for cleaning sampling equipment and containers, sample handling, and transport. The written sampling plan should identify the specific methods to be employed and the rationale for variances from the guidance provided here.

Detailed written prototols, or standard operating procedures (SOPs) should be developed and used for field collection activities. Equipment used for making field measurements (e.g. bathymetric survey equipment) should have a quality assurance plan which includes schedules and procedures for calibration, maintenance and repair. Operators should be familiar with these plans and trained in equipment use and operation.

The data quality objectives for a contaminant determination made as part of a 404(b)(1) evaluation are outlined in Appendix E. Because these evaluations are comparative (dredged material are compared to disposal site), all sediment samples must be handled in a similar manner. Field blanks are not generally necessary for dredged material evaluations, and field replicates are not considered useful indicators of QC for sediments.

6. REFERENCES

American Society for Testing and Materials (ASTM). 1984. "Standard guide for selecting grab sampling devices for collecting benthic macroinvertebrates," ASTM D 4387-84, November 1984.

ASTM. 1989. "Standard guide for core sampling submerged, unconsolidated sediments," ASTM D 4823-88, April 1989.

ASTM. 1991. "Standard guide for collection, storage, characterization, and manipulation of sediments for toxicological testing," ASTM E 1391-90, January 1991.

Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data. 1992. "IGLD 1985: Brochure on the International Great Lakes Datum 1985," Washington, DC.

Elliott, J.M. and C.M. Drake. 1981. "A comparative study of seven grabs used for sampling benthic macroinvertebrates in rivers," Freshwater Biology 11, 99-120.

Hummel, P.L. and R.J Krizek. 1974. "Sampling of maintenance dredgings," in Journal of Testing and Evaluation, 2(3), ASTM, Philadelphia, PA.

International Joint Commission (IJC). 1987. "Guidance on characterization of toxic substances problems in areas of concern in the Great Lakes basin: A report from the Surveillance Work Group based on the recommendations from the Monitoring in Areas of Concern Workshop held at Canada Centre for Inland Waters, October 3-4, 1985," a report to the Great Lakes Water Quality Board, Windsor, Ontario.

IJC. 1988. "Procedures for the assessment of contaminated sediment problems in the Great Lakes," by the Sediment Subcommittee to the IJC, Windsor, Ontario.

Lowe, J. and P.F. Zaccheo. 1991. "Subsurface explorations and sampling", in Foundation Engineering Handbook, H. Fand (Ed), Van Nostrand Reinhold, New York, NY.

Mudroch, A. and S.D MacKnight. 1991. CRC Handbook of Techniques for Aquatic Sediments Sampling, CRC Press, Boca Raton, FL.

National Oceanic and Atmospheric Administration (NOAA). 1992. "United State Coast Pilot, 6, Great Lakes," National Ocean Service, Washington, DC.

National Oceanic and Atmospheric Administration (NOAA). 1993. "Great Lakes Water Levels; 1992," Washington, DC.

Palmer, M. 1984. "Methods manual for bottom sediment sample collection", EPA-905-4-85-004, USEPA Great Lakes National Program Office, Chicago, IL.

Plumb, R.H. 1981. "Procedures for handling and chemical analysis of sediment and water samples," Technical Report EPA/CE-81-1, Environmental Protection Agency/Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sly, P.G. 1969. "Bottom sediment sampling," in Proceedings of 12th Conference on Great Lakes Research, International Association of Great Lakes Research,

Smith, J.B. and J.E. Clausner. 1993. "An inexpensive method for vibracoring sands and fine-grained sediments in shallow water," Dredging Rersearch Technical Note DRP-2-06, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers (USACE). 1972. "Soil sampling," Engineer Manual EM 1110-2-1907, Office of the Chief of Engineers, Washington, D.C.

USACE. 1983. "Dredging and dredged material disposal," Engineer Manual EM 1110-2-5025, Office of the Chief of Engineers, Washington, D.C.

USACE. 1987. "Safety and health requirements manual," EM 385-1-1, Office of the Chief of Engineers, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1977. "Methods manual for bottom sediment sample collection", Region V, Great Lakes Surveillance Branch, Chicago, IL.

USEPA. 1985. "Sediment sampling quality assuirance user's guide," EPA-600/4-85-048, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

USEPA/USACE. 1992. "Ecological evaluation of proposed discharge of dredged material into ocean waters," Chapter 8, Collection and preservation of samples, USEPA Office of Marine and Estuarine Protection, Washington DC.

USEPA/USACE. 1998. "Evaluation of dredged material proposed for discharge to waters of the United States: Testing Manual (Inland Testing Manal)," EPA-823-B-98-004, Office of Water, Washington DC.

U.S. Geological Survey. 1978. "National handbook of recommended methods for water-data acquisition," Chapter 3, Sediments, USGS Office of Water Data Coordination, Reston, VA.

U.S. Navy. 1988. "U.S. Navy Diving Manuals," NAVSEA 0994-LP-001-9010 and NAVSEA 0094-LP-001-9020, Revision 2, Naval Sea Systems Command, Washington, DC.

Winterkorn, H.F. and H. Fang. 1975. Foundation Engineering Handbook. Van Nostrand Reinhold, New York, New York.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
2. LOCATION (Coordinates or Station)			
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
		15. ELEVATION GROUND WATER	
6. DIRECTION OF HOLE [ ] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.		16. DATE HOLE	STARTED / COMPLETED
		17. ELEVATION TOP OF HOLE	
7. THICKNESS OF OVERBURDEN		18. TOTAL CORE RECOVERY FOR BORING	%
8. DEPTH DRILLED INTO ROCK		19. SIGNATURE OF INSPECTOR	
9. TOTAL DEPTH OF HOLE			

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

(TRANSLUCENT)

PROJECT | HOLE NO.

Attachment D-1

SEDIMENT SAMPLING FIELD LOG

Project: Date:

<u>Station Information</u>

Station ID:

Description:

Positioning method:

<u>Site Conditions</u>

Temperature:

Precipitation:

Wind:

Waves/current:

<u>Elevation</u>

Water surface:

Measurement equipment:

Datum:

Water depth:

Measurement equipment:

Sediment surface:

<u>Sampling Information</u>

Sampler type:

Recovery:

Sample ID:

Decontamination:

Sample volume required:

Number of sub-samples taken:

Sample homogonized:

Container(s):

<u>Visual Inspection</u>

Odor:

Color:

Texture/grain size:

Remarks:

Log prepared by: ________________________________

FROM			
	PROJECT		LOCATION
	HOLE NO.	DEPTH: FROM— TO—	
		ELEVATION	
	SAMPLE NO.	CLASSIFICATION	
		TYPE: ☐ DISTURBED ☐ UNDISTURBED	
	REMARKS		
	DATE	INSPECTOR	

ENG FORM 1742 ☐ BAG ☐ JAR OF
1 JAN 49

FROM			
	PROJECT		LOCATION
	HOLE NO.	DEPTH: FROM— TO—	
		ELEVATION	
	SAMPLE NO.	CLASSIFICATION	
		TYPE: ☐ DISTURBED ☐ UNDISTURBED	
	REMARKS	CONTAMINATED SAMPLE	
	DATE	INSPECTOR	

ENG FORM 1742a ☐ BAG ☐ JAR OF 16-57597-2 GPO
1 OCT 65

U.S. Army Corps of Engineers

Chain of Custody Record
(ER 1110-1-263)

Proj. No.	Project Name					Number of Containers								Remarks:
Sampler : (Signature)														
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number									

Sampler Relinquished by:	Date/Time	Received by: (Sig.)	Date/Time	Hazards Associated with Samples
Relinquished by: (Sig.)	Date/Time	Received by: (Sig.)	Date/Time	
Relinquished by: (Sig)	Date/Time	Received for Laboratory by: (Sig.)	Date/Time	Remarks at time of receipt:
Custody Seal No.		Lab case No.:		

ENG Form 5021-R, Oct 90 Proponent: CEMP-RT

Attachment D-4

Attachment D-4